OPTICAL DATA THROUGHPUT PROTECTION SWITCH

FIELD OF THE INVENTION

This invention generally relates to optical transport systems, optical couplings to connect equipment and optical pathways therein, and more particularly an apparatus and system for optimizing and managing said connections, to provide access to an optical path and the protection of data throughput thereon.

BACKGROUND OF THE INVENTION

In optical transport systems is it desirable to eliminate optical connectors from the optical signal path in general to reduce the costs incurred by the requirement for the use of optical signal compensation and regeneration equipment. It is also desirable to allow systems to operate at higher optical powers which allows more data to travel greater distances. The elimination of connectors may be achieved by splicing the fibers to effect the desired optical couplings. Once equipment or optical components have been connected by way of physical splices of the optical fiber, however, it becomes impractical to disconnect the fiber to gain access to the optical data path for any reason.

One reason access to an optical data path is desirable, is that it allows for the assessment of the quality and health of a span of fiber with the use of optical test equipment such as an Optical Time Domain Reflectometer (OTDR). An OTDR, once optically coupled to a span of fiber, is used to measure the quality and health of the span of fiber by producing a series of high optical power pulses and measuring the light reflected and scattered

back from the span of fiber. The high optical power pulses output by the OTDR, however, will interfere with any data on the fiber, causing bit errors.

It is therefore strongly desirable to engineer a solution which effects the elimination of optical signal connectors along the optical signal path and yet allows for access to that optical path in a manner which also protects the data from interference from equipment utilizing said access. Such a solution, for example, would allow system fiber to be measured with an OTDR during installation and configuration while preventing high optical power OTDR signals from inundating the system fiber when data is present.

SUMMARY OF THE INVENTION

This invention provides the desired solution by providing an optical data throughput protection switch which allows access to an optical path when there is no data traffic on the path, and denies access to the optical path when data is present, thereby protecting the data throughput.

The optical data throughput protection switch consists of a controllable switch and a controlling means. The controllable switch is optically coupled to a first optical path and also optically coupled to the termination of a second optical path. The controllable switch is controlled by the controlling means and functions to enable and disable optical coupling between the termination of the second optical path and the first optical path. The result is that the data throughput on the first optical path can be

controllably protected from optical signals of the second optical path.

The optical data throughput protection switch simultaneously addresses both the desirability to reduce the number of optical connectors along an optical path while enabling access to that path. The optical data throughput protection switch, once spliced into the first optical path, does not require the use of connectors along the optical path, allowing for operation at higher powers. Access to the path, which would otherwise be impracticable in a spliced system, is attained by providing controlled access to the path through a controllable switch. Access to the optical path is controlled by attenuating, blocking or otherwise disabling optical signals of the second path from propagating to the first path when data is on the first path, and allowing optical signals of the second path onto the first path when there is no data traffic on the first path. In one embodiment the controlling means are input with traffic information of the first optical path, to decide when to allow and when to disable optical coupling between the first and second optical paths. In another embodiment the controlling means controls the controllable switch using an externally set software state variable, which allows for manually enabling or disabling optical coupling between the first and second optical paths. In this way users or high level systems can manually control the controllable switch. In another embodiment the controlling means has a first mode of operation in which it uses traffic information of the first optical path to decide when to allow and when to disable optical coupling between the first and second optical paths, and a second mode of operation in

which it uses the externally set software state variable to control the controllable switch.

The optical data throughput protection switch, when used in conjunction with an OTDR optically coupled to the second optical path allows the system fiber to be measured with an OTDR during installation and configuration while preventing high power OTDR signals from inundating the system fiber when data is present.

Other aspects and features of the present invention will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a block diagram illustrating an overview of a long haul amplifier system;

FIG. 2 is a block diagram illustrating an amplifier site within the amplifier system of FIG. 1;

FIG. 3 is a block diagram illustrating a general representation of an optical data throughput protection switch according to the invention;

FIG. 4 is a block diagram illustrating a first preferred embodiment of the optical data throughput protection switch;

FIG. 5 is a block diagram illustrating a second preferred embodiment of the optical data throughput protection switch; and

FIG. 6 shows the amplifier system spectrum.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 shows an overview of a long haul amplifier system, which is the preferred context for implementation of an optical data throughput protection switch according to the invention. Amplifier equipment is located at different amplifier sites along the system to amplify an optical data signal input at one end of the system. Two such sites are illustrated in FIG. 1. A first amplifier site **80** is connected to a first fiber span **102,** preferably by a high optical power compatible connection, such as a splice **113.** The first amplifier site **80** comprises amplification equipment **70** which is optically coupled to test equipment **50**. The first amplifier site is optically coupled to a second fiber span 104 by a splice **114.** The second fiber span **104** is optically coupled to a second amplifier site **82** by a splice **111**. A third fiber span **106** is optically coupled to the second amplifier site **82** by a splice **112**. The second amplifier site comprises amplification equipment **72**.

FIG. 2 shows a more detailed view of the first amplifier site **80**. As described above, the first fiber span **102** carrying data throughput is connected to the amplifier site **80** by splice **113**. Splice **113** is connected to one end of a first fiber segment **103** the other end of which is connected to an amplifier circuit pack **60** through an input port **122** which in the preferred embodiments is a splice.

The amplifier circuit pack **60** is housed in an amplifier bay **62**, which is part of the amplification equipment **70** of FIG. 2. The amplifier circuit pack **60** has an output port **120** which in the preferred embodiment is a splice. Output port **120** is connected to one end of a second fiber segment **105**, the other end of which is connected to a splice **114**. As mentioned previously in connection with FIG. 1, splice **114** is connected to the second fiber span **104**. A third port **42** (TEST PORT) on the amplifier circuit pack **60**, which is preferably a high optical power compatible connector, connects the amplifier circuit pack **60** to the test equipment **50** such as an OTDR. Inside the amplifier circuit pack **60**, an optical data throughput protection switch **20** has a first input **11** which is connected to the input port **122** by a first portion **10** of a first optical path, and a second input **8** connected to the TEST PORT **42** of the amplifier circuit pack **60**, by a second optical path **14**. The optical data throughput protection switch **20** has an output **13** which may be connected to an input of other optics **21**, by a second portion **12** of the first optical path. Other optics **21** which typically comprises amplification equipment, such as Erbium Doped Fiber Amplifiers (EDFA), and any other optical elements normally found in an amplifier circuit pack, has an output optically coupled to output port **120**. The optical data throughput protection switch **20** acts to allow high power pulses from the test equipment **50** propagating along the second optical path **14** to pass onto the data-carrying first optical path (**10**,**12**) when testing is desired and blocks these high power pulses from the test equipment **50** propagating along the second optical path **14** from entering onto the data-carrying first optical path when data traffic is present on the first fiber span **102**.

Referring now to FIG. 3, a block diagram representation of the optical data throughput protection switch, the optical data throughput protection switch **20** comprises a controllable switch **16**, and a controlling means **18**. The controllable switch **16** has an input **11'** optically coupled by means of an optical path **10'** to a first input **11** of the switch **20**. It should be appreciated that the optical path **10'** is a continuation of the first portion **10** of the first optical path. The switch 16 has an output **13'** optically coupled by means of an optical path **12'** to an output **13** of the switch **20**. It should be appreciated that the optical path **12'** is a continuation of the second portion **12** of the first optical path. The controllable switch **16** also has an input **8'** optically coupled by means of an optical path **14'** to a second input **8** of the switch **20**. It should be appreciated that the optical path **14'** is a continuation of the second optical path **14**. The controllable switch **16** is controlled by the controlling means **18** to enable and disable optical coupling between the optical path **14'** and the data-carrying optical path (**10'**,**12'**). In this way data throughput along the first optical path (**10**,**12**) is controllably protected from optical signals which may be present on the second optical path **14**.

FIG. 4 shows a first preferred embodiment of the optical data throughput protection switch **20** illustrated generally in FIG. 3. In this embodiment, the controllable switch **16** includes a wavelength selective filter **34** which is optically coupled by the input **11'** to the optical path **10'**, and optically coupled by the output **13'** to the optical path **12'**. The controllable switch **16** includes a controllable optical signal blocker **30** which is optically coupled by means of an optical path **32** to the wavelength selective

filter **34**. The wavelength selective filter is substantially transmissive from input **11′** to output **13′** in the optical carrier wavelength bands, causing as little loss as possible to the data signal propagating along the data-carrying optical path (**10′**,**12′**) as it traverses the filter, a consequence of which is that the signals in the optical carrier wavelength bands do not propagate from input **11′** along the optical path **32**. The optical carrier wavelength bands include the C-band, and the L-band illustrated in FIG. 6 and described below. The controllable optical signal blocker **30** is optically coupled by the input **8′** to the optical path **14′**. The wavelength selective filter **34** in the preferred embodiment is configured so that optical signals propagating along the optical path **32** of wavelengths particular to the OTDR **50**, are routed through the input **11′** to propagate along the optical path **10′**, or through the output **13′** to propagate along the optical path **12′**, and operates so that those optical signals when scattered or reflected back towards the wavelength selective filter **34** from the elements and fibers farther down the continuation of optical path **10′** or **12′** respectively, are routed back along the optical path **32**, so that they can be analyzed by the OTDR **50**. In this way the wavelength selective filter may operate to enable testing of the fiber and associated equipment in either direction along the data-carrying first optical path (**10**,**12**).

In this preferred embodiment, the controlling means **18** is input with traffic information of the optical path **10′** using a 1% tap **22**. The controlling means **18** includes a traffic detection means **15**, a logic means **17**, and a controller **19**. In the preferred embodiment the traffic detection means **15** includes a photodiode which converts

optical power into electrical signals, and some logic capacity for processing the electrical signals. The processing could take place in hardware and/or software and typically employs a digital signal processor (DSP) or microprocessor. Of the many types of traffic detection that could be employed in the embodiment, occurring at different levels of resolution, information, and cost, one is discussed in association with this preferred embodiment. Two other types of traffic detection will be discussed below as alternative embodiments. This preferred embodiment uses low resolution traffic detection which simply assesses the presence or absence of optical signals above a set threshold, the threshold set somewhere between expected noise levels, and the expected power levels of optical signals to be detected. This type of detection provides no information about the optical signal other than its presence or absence, and is a relatively low-cost type of traffic detection. The logic means **17** of the controlling means **18** is input with information regarding the presence or absence of data throughput by the traffic detection means **15**. The logic means **17** which may be implemented in hardware and/or software decides, based on the information provided to it regarding the traffic on the optical path **10'**, how to control the controllable optical signal blocker **30**. In general the controller **19** controls the controllable optical signal blocker in accordance with the decision reached by the logic means **17**. In the preferred embodiment, the controllable optical signal blocker **30** operates in one of two states, or is controlled to operate in one of two states. One state of the optical signal blocker **30** is the blocking state, in which the optical signal blocker **30** substantially blocks, attenuates or otherwise prevents optical signals propagating along the optical path **14'** from

propagating along the optical path **32**. The second state of the optical signal blocker **30** is the transparent state, in which the optical signal blocker **30** substantially allows, transmits or otherwise enables optical signals propagating along the optical path **14'** to propagate along the optical path **32**. In this preferred embodiment, the optical signal blocker **30** is a Variable Optical Attenuator (VOA), also known as a Voltage Controlled Attenuator (VCA) controllable by electrical outputs of the controller **19**. When in the transparent state, the VOA **30** preferably creates an optical signal loss of less than or equal to 1 decibel in the optical signals propagating onto the optical path **32** from the optical path **14'**. When in a blocking state, the VOA **30** preferably creates a loss of greater than 30 decibels in the optical signals propagating onto the optical path **32** from the optical path **14'**. In this preferred embodiment, when the traffic information from tap **22** indicates the presence of traffic on the optical path **10'**, the controlling means **18** operates to control the VOA **30** so that the VOA **30** goes into a first state and blocks or attenuates any optical signals propagating along optical path **14'**. When the traffic information from tap **22** indicates the absence of traffic on the optical path **10'**, the controlling means **18** operates to control the VOA **30** so that the VOA **30** goes into a second state and allows or transmits any optical signals propagating along the optical path 14'.

FIG. 5 shows a second preferred embodiment of the optical data throughput protection switch **20** illustrated generally in FIG. 3. In this embodiment, the controllable switch **16** has the same functionality and structure as that of the first embodiment of the optical data throughput protection switch. In this preferred embodiment, the

controlling means **18** includes a software state variable **24** which is an active local setting, a logic means **17**, and a controller **19**. In the preferred embodiment the software state variable **24** is an active local setting which can be set externally. The preferred embodiment contemplates the setting of the software state variable **24** by an external operator, or a remote central network managing center, or a system which performs operation, management and monitoring of the network on a scale larger than a single amplifier site, or in general any other external entity which requires a mechanism to manually control the optical data throughput protection switch. The logic means **17** which may be implemented in hardware and/or software decides, based on the software state variable **24** how to control the controllable optical signal blocker **30**. In general the controller **19** controls the controllable optical signal blocker **30** in accordance with the decision reached by the logic means **17**. The controllable optical signal blocker **30** of this preferred embodiment is the same as that of the first preferred embodiment. In this preferred embodiment, when the software state variable **24** indicates that the optical signals propagating along the optical path **14'** should be blocked, the controlling means **18** operates to control the VOA **30** so that the VOA **30** goes into a first state and blocks or attenuates any optical signals propagating along the optical path **14'**. When the software state variable **24** indicates that the optical signals propagating along optical path **14'** should not be blocked, the controlling means **18** operates to control the VOA **30** so that the VOA **30** goes into a second state and allows or transmits any optical signals propagating along the second optical path **14'**.

FIG. 6 shows the amplifier spectrum indicating the wavelengths passed and amplified by an amplifier site, and also shows the wavelengths used in operating an OTDR. The wavelengths of the spectrum correspond to wavelengths that a wavelength selective filter would be tuned to in order to optimize performance of the optical data throughput protection switch **20** when used with an OTDR. The data carrier wavelength bands include the C-band (conventional band), the original cost effective band of wavelengths characteristic of standard erbium doped fiber amplifiers, and the L-band (long band), the typically less efficient more expensive to implement data carrier wavelength band. In the diagram, it can be seen that the wavelengths of the data carried in the C-Band and the L-band do not overlap wavelengths used by an OTDR. However if the high power pulses from the OTDR were allowed to propagate through the data-carrying fiber, due to the extreme power levels of the OTDR pulses, any data signals in the C-band and L-band would be interfered with. The frequency differentiation between the OTDR pulses and the data bands can be advantageously used to choose a wavelength selective filter **34** shown in figures 4 and 5 of the first and second preferred embodiments, such that as described above, the traffic on the first fiber span **102** encounters as little loss as possible while traversing the filter **34**, and OTDR pulses propagating along optical path **32** are directed down the optical fiber which is being tested.

There are many possible variations and embodiments of the invention which have not been illustrated, some of which will be described as follows.

Two other possible types of traffic detection that could be employed in other embodiments are medium and high resolution traffic detection. Medium resolution traffic detection is capable of detecting low frequency modulation of the carrier signal, such modulation carrying information often referred to as signal tags. This type of traffic detection is more reliable for detecting signals than low resolution traffic detection, and can extract information from the signal tags typically regarding the character and origin of optical signals. This type of detection provides more information than low resolution traffic detection, but is also more costly. High resolution traffic detection processes signals at the data level, extracting all of the data from the optical signal. This type of traffic detection can extract header information from the data stream, which contains detailed international standardized information. This type of traffic detection extracts the most information and is the most costly of the three types described. In utilizing these different types of traffic detection, the logic means **17** of the controlling means **18** is input with information regarding not only the presence or absence of data throughput, but also any other desired information from the traffic information extracted by the traffic detection means **15**.

As a hybrid of the first and second preferred embodiments, shown in FIGs 4 and 5, the controlling means **18** could comprise both a traffic detection means **15** input with traffic information from a tap **22**, and a software state variable **24** which can be externally set. This embodiment could automatically control the optical data throughput protection switch **22** based on traffic information in a first mode of operation, while providing a manual override to a

user in a second mode of operation, or an override to high level systems which could also change the software state variable.

In a more advanced hybrid embodiment, the controlling means **18**, employing medium or high resolution traffic detection, uses priority information associated with optical signals on the data-carrying path to decide, in spite of a manual override request by a user or a high level system, to give priority to protecting the optical signal on the data-carrying path.

In one application of the second preferred embodiment, the software state variable is set by a network management center after receiving an alarm state indicating a failure and the need to use an OTDR to perform fault diagnosis on a particular span of fiber. The controlling means **18** controls the optical signal blocker **30** so that OTDR pulses are allowed to pass onto the optical path **32**, to test the particular fiber span.

The connections **11′** and **13′** between the wavelength selective filter **34** and the data-carrying optical path (**10′**, **12′**), although made with physical splices in the preferred embodiment could be made with high optical power compatible connectors in alternate embodiments, as could the connections between the optical path **32** and the optical signal blocker **30**, and connections between the optical path **32** and the wavelength selective filter **34**.

In further alternative embodiments, the controllable optical signal blocker **30** could be an optical switch, which instead of attenuating optical signals simply directs the optical signal away from optical path **32**, for

example by dumping the optical signal to an unconnected or otherwise unused port. The optical signal blocker **30** could also be an optical shutter or beam stop which mechanically blocks optical signals by way of a metallic shutter which may be controllably placed into and out of the optical signal path. In general, the number of states the optical signal blocker **30** has, and the levels of transmission or blocking it can be set to can correspond to whatever number of states and whatever levels of transmission or blocking that are required by the particular application of the optical data throughput protection switch.

In the first and second preferred embodiments, the wavelength selective filter **34** connecting the optical path **32** to the data-carrying optical path (**10′**, **12′**), can in general be any three port optical component which has the desired optical characteristics of substantially complete transmission of optical signals in the C-band and L-band across **11′** and **13′**, and appropriate routing of OTDR signals in the direction of the fiber to be tested.

It also should be noted that in place of the test equipment **50** shown as an OTDR, other kinds of test equipment such as an Optical Return Loss (ORL) Meter, or even non-test equipment may require controlled access to the data-carrying first optical path. The other test equipment or even non-test equipment can be connected to the second optical path 14 as the desired access to the first optical path dictates.

In the first and second preferred embodiments, the controllable switch **16** has been depicted as comprising a wavelength selective filter **34**, an optical path **32**, and a controllable optical signal blocker **30**. In other embodiments, the controllable switch **16** may comprise a

single element or other elements that function to controllably enable and disable optical signals propagating along the optical path **14′**, from entering the data-carrying optical path (**10′**, **12′**). Such a component could be a controllable 1-by-2 switch which could simply switch to optically couple input **11′** with output **13′** disabling any optical coupling between input **8′** and both input **11′** and output **13′** when access to the data-carrying path is to be denied. When access to the data-carrying path is to be allowed, the 1-by-2 switch could operate to optically couple input **8′** to either input **11′** or output **13′** to enable OTDR pulses to test the desired fiber, a side effect of which is the interruption of optical coupling between input **11′** and output **13′**. This embodiment is less preferred than the first and second preferred embodiments due to the risk of interfering with the data throughput in the case of a failure causing accidental switching of the 1-by-2 switch. The component could also be a three or four port Acousto-Optic Tunable Filter (AOTF), or in general any multiport tunable filter which is controllable to allow substantially complete transmission along the data-carrying path (**10′**, **12′**), allows OTDR pulses onto the data-carrying path (**10′**, **12′**) when desired, and dumps the OTDR pulses to an unconnected or otherwise unused port or blocks them when data throughput along (**10′**, **12′**) is to be protected.

It also should be appreciated that although the preferred embodiments may have implicitly described the data throughput as propagating in one direction along the data-carrying first optical path (**10**, **12**), the invention is not limited to one way traffic, and contemplates that data throughput may be propagating in two directions along the data-carrying first optical path (**10**, **12**).

What has been described is merely illustrative of the application of the principles of the invention. Other arrangements and methods can be implemented by those skilled in the art without departing from the spirit and scope of the present invention.